Summer-winter transitions in Antarctic aquatic ecosystems

An IPY initiative extending field event helicopter support from February into April allowed scientists to find out what happens to aquatic ecosystems during the summer-winter transition.


Small pond immediately after freezing. The thick carpet of microbial mat is very clear through the ice

Antarctica is a continent with plenty of “water” but precious little in the liquid state that most life requires. Where liquid water does exist, microbial ecosystems develop that are oases of biological diversity in otherwise barren landscapes. One of the commonest type of liquid water habitat are small ponds that freeze solid in winter but melt out to varying degrees in summer. These systems are widespread and typically have prolific microbial communities dominated by cyanobacterial mats that frequently cover the floor of the ponds.

For years our understanding of life in these ponds has been almost exclusively restricted to the summer period, when the pond communities are metabolically active and growing conditions are relatively mild. However, these communities do not develop anew each year and it seems to be perennial growth habit in the face of extreme winter conditions that allows microbial mats to dominate aquatic biodiversity in much of Antarctica. What has eluded our understanding to date is the conditions that accompany freezing of these shallow ponds, and how microbial activity responds to and tolerates the changing conditions as water turns to ice. In the best traditions of IPY, a one-off injection of support enabled us to take a substantial step forward in understanding these important communities. In this case it was the decision of the New Zealand and United States Antarctic Programmes to provide field support beyond the normal operational period, in this case extending helicopter access to field sites from the usual limit of early February January out until early April. This allowed a team of NZ scientists to monitor pond dynamics through a large proportion of the freezing period.


Drilling for water in April

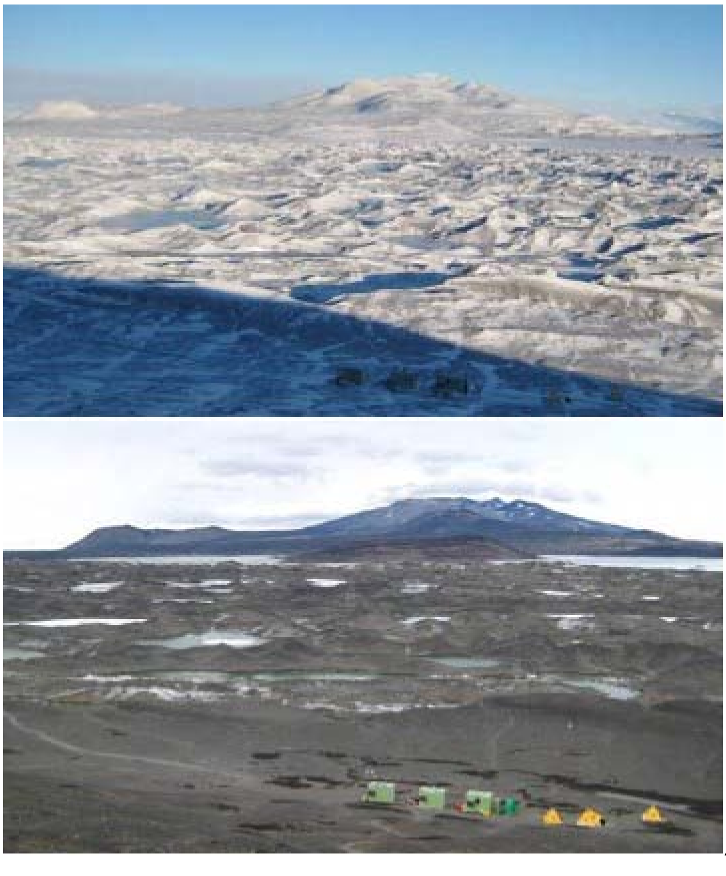
The strategy that we adopted was to commence observations in mid-January and continue until mid April. This would see the shift from 24 h daylight and temperatures near 0 degrees C, to just a few hours of daylight and temperatures below -30C. The research site selected for the study was on the McMurdo Ice Shelf close to Bratina Island (78o00’S, 165o35’E), a section of ice shelf that bears large numbers of well-developed meltwater ponds. This is an established research site and already had a number of field huts set up as laboratories; for this project these hits were “winterised” by installing heaters and electric light. Both of these were to become essential for the field team as the project progressed.


keeping equipment free of ice was a constant battle

Ice began to form on the ponds early in February and it was only a few days later that it was thick enough to walk on. For the duration of the field programme ice thickness steadily increased, at approximately 1 cm per day. Water samples and instrument measurements were taken every few days from seven different ponds and a detailed time-line of the freezing process and its chemical and biological consequences was obtained. The team were able to follow the ponds until almost the entire volume had frozen. This work was not without a degree of difficulty. Working outside with liquid water at -30oC is difficult – all the water wants to do is freeze - and techniques were adapted by careful application of flasks of hot water, body heat and insulated boxes to make sure that samples and field instruments were not compromised. With all of these precautions, sampling at low temperature took much longer than during the summer period and frequently several attempts were necessary to get the simplest data sets.


pattern of bubble formation in a chunk of pond ice

Before the field work was undertaken, models had suggested a rapid depletion of oxygen, accumulation of carbon dioxide and a decline in pH, that sulphide would appear in the water and the concentrations of salts would steadily increase as the volume of water declined. Only the last of these predictions proved true. By the end of the observations, what started out as almost fresh water had become a small volume of hypersaline brine. However, rather than oxygen depletion, oxygen concentration increased rapidly to levels vastly in excess of those seen during summer, that would be toxic to many organisms. At its peak, we saw oxygen concentrations five times higher than in air-saturated water. The source of this oxygen was two-fold. Firstly, the ice was initially clear enough to allow photosynthesis to proceed rapidly, with large amounts of oxygen released from the microbial mats; secondly, ice formation excluded dissolved oxygen which resulted in a physical concentration to exacerbate the biological process. Eventually the water contained so much dissolved oxygen that it came out of solution as bubbles that were frozen into the ice. These bubbles formed daily bands reflecting changes in the rate of ice formation; large bubbles tend to form when ice is forming quickly (photo). Oxygen accumulated to such an extent during the early phases of freezing that it imparted a legacy on the rest of the freezing process. Concentrations remained at or above 100% saturation until almost all of the pond volumes were frozen. As for carbon dioxide accumulation, which we expected to increase water acidity, the under-ice photosynthesis was so rapid that it depleted carbon dioxide to very low levels, and water remained alkaline throughout the freezing process. Rather than tolerate of low oxygen, near darkness, acidic and sulphide-rich conditions prior to freezing, most pond organisms were required to tolerate super-high oxygen concentration, near darkness, a salinity increase and alkaline conditions followed by freezing. How they do this, and implications for these microbial ecosystems of climatic changes that might affect the timing, extent and speed of freezing are new foci of research interest.


April and January at Bratina Island

Much information remains to come from this field event, as samples returned to NZ are slowly analysed. However, the basic fact that Antarctic ecosystems are amongst the most extraordinary on earth, and as such will always have some new way of surprising the scientists who study them has been confirmed. The research team plans to develop this IPY programme on the McMurdo Ice Shelf by extending it to cover other nearby cryo-ecosystems. There is a growing appreciation of the potential for ice-based ecosystems, supporting a range of highly resilient organisms, to provide important refugia for Antarctic biota during times of environmental change as well as providing important habitats in their own right. Ice is still the dominant element of Antarctic landscapes, and ice-based ecosystems are fundamental elements of the continent's biodiversity.


A rare sight – sunset at Bratina Island

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Bratina Island Huts

On February 25th 2009, the IPY Joint Committee will release a report on 'The State of Polar Research'. In the lead-up to this event, major IPY research projects are releasing information for the press, and making themselves available for media enquiries. A wide range of projects will be profiled reflecting the diversity of IPY. For more information, please visit http://www.ipy.org/index.php?ipy/detail/feb09_projects/